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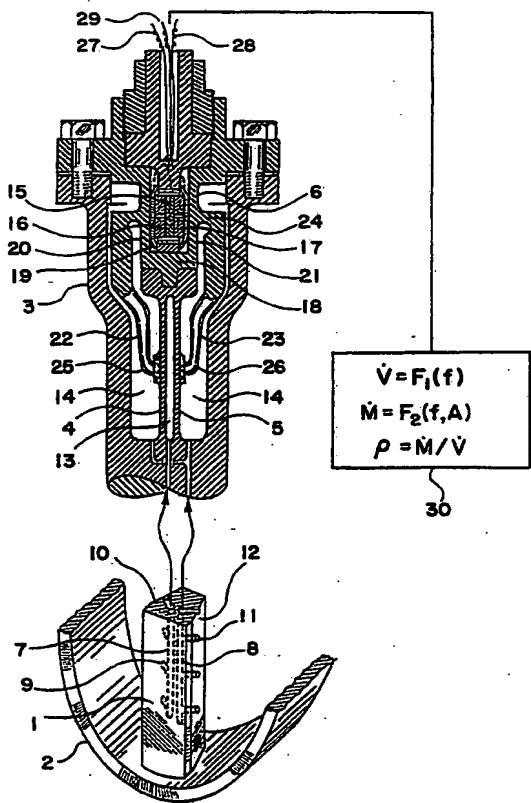
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**(54) Title: NOISE REJECTING VORTEX FLOWMETER**

**(57) Abstract**

A vortex flowmeter comprises a vortex generating bluff body (1), a first pressure compartment (13) with two end walls provided by two thin planar members (4 and 5), which first pressure compartment (13) receives fluid pressure existing at a first side surface (10) of the bluff body (1), a second pressure compartment (14) straddling the combination of the two thin planar members (4 and 5) and the first pressure compartment (13), which second pressure compartment (14) receives fluid pressure existing at a second side surface (12) of the bluff body (1), and a transducer (3) converting relative flexural vibration between the two thin planar members (4 and 5) into a fluctuating electrical signal representing vortex shedding from the bluff body (1).



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## 1 . NOISE REJECTING VORTEX FLOWMETER

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3 This invention relates to a vortex flowmeter that determines  
4 the volume flow rate of a fluid as a function of the frequency of  
5 vortex shedding, which vortex flowmeter has an optional feature that  
6 determines the mass flow rate of the fluid as a function of the  
7 frequency of vortex shedding and the amplitude of fluctuating fluid  
8 dynamic force created by the vortex shedding phenomenon and determines  
9 the density of the fluid as the ratio of the mass flow rate to the  
10 volume flow rate of the fluid.

11

Under a carefully controlled laboratory condition wherein the noise created by the structural vibration of the flowmeter body is kept at the minimum level and the fluid dynamic force created by the vortex shedding phenomenon is amplified to the maximum level, a well designed vortex flowmeter is capable of measuring air flow as low as 1 meter per second and water flow as low as 0.05 meter per second. The performance of an industrial vortex flowmeter can approach the standard set under the carefully controlled laboratory condition when the industrial vortex flowmeter is equipped with an optimized noise rejecting vortex sensor and the fluid dynamic force created by the vortex shedding phenomenon is detected in a highly amplified form. The present invention teaches such a high performance vortex flowmeter.

24

25 The primary object of the present invention is to provide a vortex  
26 flowmeter that detects the vortex shedding from a bluff body of an  
27 elongated cylindrical shape disposed across a fluid stream by detecting  
28 a relative flexural deflection between two thin planar members or  
29 diaphragms separating a first pressure compartment therebetween from  
30 a second pressure compartment straddling the two thin planar members  
31 and the first pressure compartment, wherein the first pressure  
32 compartment receives the fluid pressure existing at a first side  
33 surface of the bluff body and the second pressure compartment receives  
34 the fluid pressure existing at a second side surface of the bluff body  
35 opposite to the first side surface thereof.

36 Another object is to provide the vortex flowmeter described in the  
37 above-presented primary object of the present invention, wherein a  
38 piezo electric relative motion sensor with two vibration sensing

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1 elongated members respectively transmitting the flexural vibration  
2 of the two thin planar members to a piezo electric disc element  
3 converts the relative flexural vibration between the two thin planar  
4 members into an alternating electrical signal representing the vortex  
5 shedding from the bluff body.

6 A further object is to provide the vortex flowmeter described in  
7 the primary object of the present invention, wherein a capacitive  
8 relative motion sensor generating a fluctuating electrical signal  
9 related to the electrical capacitance between the two thin planar  
10 members converts the relative flexural vibration between the two thin  
11 planar members into an alternating electrical signal representing the  
12 vortex shedding from the bluff body.

13 Yet another object is to provide the vortex flowmeter that  
14 determines the volume flow rate of fluid as a function of the frequency  
15 of the alternating electrical signal generated by the piezo electric or  
16 capacitive relative motion sensor.

17 Yet a further object is to provide the vortex flowmeter that  
18 determines the mass flow rate of fluid as a function of the frequency  
19 and amplitude of the alternating electrical signal generated by the  
20 piezo electric or capacitive relative motion sensor, and determines  
21 the density of fluid as the ratio of the mass flow rate to the volume  
22 flow rate of fluid.

23 These and other objects of the present invention will become clear  
24 as the description thereof progresses.

25

26 The present invention may be described with a greater clarity and  
27 specificity by referring to the following figures :

28 Figure 1 illustrates an embodiment of the vortex flowmeter of the  
29 present invention employing two thin planar members constituting the  
30 end walls of two pressure compartments and a piezo electric relative  
31 motion sensor detecting relative flexural vibration between the two  
32 thin planar members.

33 Figure 2 illustrates an embodiment of the piezo electric disc  
34 element and the noise cancelling electric circuit included in the  
35 piezo electric relative motion sensor.

36 Figure 3 illustrates another embodiment of the combination of the  
37 two thin planar members constituting the end walls of the two pressure  
38 compartments and a piezo electric relative motion sensor detecting

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1 relative flexural vibration between the two thin planar members.  
2 Figure 4 illustrates an embodiment of the combination of the two  
3 thin planar members constituting the end walls of the two pressure  
4 compartments and a capacitive relative motion sensor detecting  
5 relative flexural vibration between the two thin planar members.  
6

7 In Figure 1, there is illustrated an embodiment of the vortex  
8 flowmeter of the present invention comprising a vortex generating  
9 bluff body 1 of an elongated cylindrical shape, that is disposed at  
10 least partially across a fluid stream moving through a conduit 2, and  
11 a transducer 3 including two thin planar members 4 and 5 constituting  
12 the end walls of two pressure compartments and a piezo electric  
13 relative motion sensor 6 detecting relative flexural vibration between  
14 the two thin planar members 4 and 5. The bluff body 1 has two pressure  
15 transmitting holes 7 and 8 disposed therethrough following the length  
16 of the bluff body 1, wherein the first hole 7 has one or more openings  
17 9 open to a first side surface 10 of the bluff body 1, while the  
18 second hole 8 has one or more openings 11 open to a second side  
19 surface 12 of the bluff body 1 opposite to the first side surface 10  
20 thereof. The transducer 3 has a first pressure compartment 13 disposed  
21 intermediate the two thin planar members 4 and 5 respectively  
22 constituting the two opposite end walls thereof, and a second pressure  
23 compartment 14 straddling the combination of the two thin planar  
24 members 4 and 5, and the first pressure compartment 13. The first  
25 pressure transmitting hole 7 with one extremity open to the first side  
26 surface 10 of the bluff body 1 has the other extremity open to the  
27 first pressure compartment 13, while the second pressure transmitting  
28 hole 8 with one extremity open to the second side surface 12 of the  
29 bluff body 1 has the other extremity open to the second pressure  
30 compartment 14. The piezo electric relative motion sensor 6 has a  
31 piezo electric disc element 15 that includes two sets of split  
32 electrodes 16 and 17 respectively disposed on the two opposite sides  
33 of the piezo electric disc element 15, which combination of the piezo  
34 electric disc element and the electrodes is disposed within a closed  
35 cavity of the transducer container vessel 18 in a parallel relationship  
36 to the plane of symmetry located intermediate the two thin planar  
37 members 4 and 5. The piezo electric disc element 15 extends across the  
38 reference plane perpendicular to the plane of symmetry, and each of

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1 the two sets of electrodes 16 and 17 disposed on each of the two  
2 opposite sides of the piezo electric disc element 15 is split along  
3 the reference plane. The stacked combination of the piezo electric  
4 disc element 15 and the two sets of split electrodes 16 and 17, that  
5 is wrapped up by an electrically insulating dielectric wrapper 19,  
6 is disposed intermediate two opposite thin walls 20 and 21 of the  
7 closed cavity of the transducer container vessel 18 in a compressed  
8 relationship therebetween. A pair of elongated vibration sensing  
9 members 22 and 23 extending towards a common direction are respectively  
10 disposed next to the two opposite thin walls of the closed cavity,  
11 wherein the first angled extremity of each of the two elongated  
12 vibration sensing members 22 and 23 is anchored to a reinforcing rib  
13 24 extending across each of the two opposite thin walls 20 and 21  
14 along the reference plane, while the over-hanging second extremities  
15 25 and 26 are under pressurized contact respectively with the two thin  
16 planar members 4 and 5. The lead wires originating from various  
17 electrodes included in the two sets of split electrodes 16 and 17  
18 extend out of the transducer container vessel 18.

19 The fluid pressures respectively existing at the two opposite side  
20 surfaces 10 and 12 of the bluff body 1 fluctuate in an alternating mode  
21 therebetween as the vortices are shed from the two opposite side  
22 surfaces 10 and 12 of the bluff body 1 in an alternating mode. The two  
23 alternatively fluctuating fluid pressures respectively transmitted to  
24 the two pressure compartments 13 and 14 create a relative flexural  
25 vibration between the two thin planar members 4 and 5, which relative  
26 flexural vibration in turn alternatively compresses and decompresses  
27 the two opposite halves of the piezo electric disc element 15  
28 respectively located on the two opposite sides of the reference plane  
29 defined by the two reinforcing ribs 24 respectively included in the  
30 two opposite thin walls of the closed cavity housing the transducer  
31 elements. The electromotive forces generated by the two opposite halves  
32 of the piezo electric disc element 15 respectively located on the two  
33 opposite sides of the reference plane are transmitted through two of  
34 the three lead wires 27, 28 and 29, while the third lead wire grounds  
35 the electrodes which are not connected to the two lead wires. It should  
36 be noticed that the construction of the transducer 3 has a geometry  
37 that is symmetric about the plane of symmetry located intermediate the  
38 two thin planar members 4 and 5 and, consequently, the inertia force

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1 created by any structural vibration of the transducer 3 and experienced  
2 by all component elements in the transducer 3 is symmetric about  
3 the plane of symmetry, while the differential pressure forces across  
4 the two thin planar members 4 and 5 created by the vortex shedding  
5 from the bluff body 1 are antisymmetric about the plane of symmetry.  
6 By using a simple electric circuit exemplified by the embodiment shown  
7 in Figure 2, the electrical signal generated by the symmetric component  
8 of the forces can be rejected, and the electrical signal generated by  
9 the antisymmetric component of the forces can be selectively extracted  
10 from the transducer 3. Consequently, the transducer 3 provides an  
11 alternating electrical signal generated exclusively by the vortex  
12 shedding from the bluff body 1, which alternating electrical signal is  
13 substantially free of the noise created by the structural vibration of  
14 the transducer 3. The frequency of such an alternating electrical  
15 signal is the same as the frequency of the vortex shedding from the  
16 bluff body 1, and the amplitude thereof is proportional to the fluid  
17 density times a power function of the fluid velocity (typically a  
18 square function for a well designed pressure openings included in the  
19 bluff body). A data processor 30 determines the fluid velocity  $U$  or the  
20 volume flow rate of fluid  $V$  as a function of the frequency  $f$  of the  
21 alternating electrical signal provided by the transducer 3, and  
22 determines the mass flow rate of fluid  $M$  as a function of the frequency  
23  $f$  and the amplitude  $A$  of the alternating electrical signal provided by  
24 the transducer 3. The data processor 30 can also determine the fluid  
25 density as the ratio of the mass flow rate  $M$  to the volume flow rate  
26  $V$ . It should be understood that, in an alternative design, the  
27 reinforcing ribs 24 included in the two opposite thin walls 20 and 21  
28 of the closed cavity housing the piezo electric disc element 15 may be  
29 omitted and the angled first extremities of the two elongated  
30 vibration sensing members 22 and 23 may be anchored directly to the two  
31 opposite thin walls 20 and 21. The transducer 3 and the bluff body 1  
32 may be constructed into a single integral structure, or connected to  
33 one another rigidly by means of a mechanical coupling or welding.  
34 Of course, the transducer 3 and the bluff body 1 may be constructed in  
35 a structurally separate and independent arrangement and connected to  
36 one another by a pair of flexible or rigid tubings transmitting the  
37 fluid pressures existing at the two opposite side surfaces 10 and 12 of  
38 the bluff body 1 to the two pressure compartments 13 and 14,

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1 respectively. The illustrative embodiment shown in Figure 1 as well as  
2 the other embodiments shown in Figures 3 and 4 can be used to construct  
3 an in-line type or an insertion type vortex flowmeter.  
4 In Figure 2, there is illustrated an embodiment of the stacked or  
5 layered combination of the piezo electric disc element 15 and the two  
6 sets of split electrodes 16 and 17 respectively included in the two  
7 opposite sides of the piezo electric disc element 15. In the particular  
8 illustrative embodiment, one of the first pair of split electrodes 16  
9 located on one side of the piezo electric disc element 15 and on  
10 one side of the reference plane including the demarcation line between  
11 the first pair of split electrodes 16 is connected to a first amplifier  
12 31 by means of the lead wire 27, while one of the second pair of split  
13 electrodes 17 located on the other side of the piezo electric disc  
14 element 15 and on the other side of the reference plane is connected to  
15 a second amplifier 32 by means of the lead wire 28, wherein the two  
16 amplifiers 31 and 32 include a signal level balancing means 33 such as  
17 one or more variable resistors. The electrodes not connected to the  
18 amplifiers 31 and 32 are grounded by means of the lead wire 29. The  
19 antisymmetric component of the forces experienced by the component  
20 elements in the transducer 3 alternatively compresses and decompresses  
21 the two opposite halves of the piezo electric disc element 15  
22 respectively located on the two opposite sides of the reference plane,  
23 while the symmetric component of the forces experienced by the  
24 component elements of the transducer 3 compresses or decompresses both  
25 of the two opposite halves of the piezo electric disc element 15.  
26 When the piezo electric disc element 15 is polarized in the same  
27 direction over both of the two opposite halves thereof, the anti-  
28 symmetric component of the forces created by the vortex shedding from  
29 the bluff body 1 produces two alternating electrical signals of the  
30 same phase (same sign) respectively from the two electrodes connected  
31 to the two amplifiers 31 and 32, which two alternating electrical  
32 signals are additively combined to provide the alternating output  
33 electrical signal 34 representing the vortex shedding from the bluff  
34 body 1, while the symmetric component of the forces created by the  
35 structural vibration of the transducer 3 produces two alternating  
36 electrical signals with 180 degree phase angle difference therebetween  
37 (opposite sign) respectively from the two electrodes connected to the  
38 two amplifiers 31 and 32, which two alternating electrical signals of

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1 opposite signs are cancelled out in the additive combination process  
2 wherein the signal balancing means 33 is set to a value that exactly  
3 balances the amplitudes of the two alternating electrical signals of  
4 opposite signs respectively amplified by the two amplifiers 31 and 32.  
5 The alternating output electrical signal 34 is supplied to the data  
6 processor 30 included in the embodiment shown in Figure 1, that  
7 determines the volume flow rate of fluid and/or the mass flow rate  
8 as well as the density of the fluid. It should be mentioned that, in  
9 an alternative design, two split electrodes located on the same side  
10 of the piezo electric disc element and respectively on the two  
11 opposite sides of the reference plane may be connected to an inverting  
12 amplifier and a noninverting amplifier in a parallel arrangement,  
13 respectively, wherein the noise is cancelled therebetween by means of  
14 the signal level balancing means between the two amplifiers, or the  
15 two split electrodes may be connected to two opposite terminals of  
16 an electrical circuit in a series arrangement, wherein the alternating  
17 output electrical signal is obtained by a differential combination  
18 and the noise is cancelled by an additive combination. In another  
19 alternative design, a piezo electric disc element with the two opposite  
20 halves respectively polarized in two opposite directions may be  
21 employed in conjunction with various arrangements of the electrodes,  
22 wherein the alternating output electrical signal is obtained and the  
23 noise is cancelled by means of additive combination process using a  
24 parallel circuit or by means of differential combination using a series  
25 circuit.

26 In Figure 3, there is illustrated another embodiment of the piezo  
27 electric transducer operating on the same principles as those  
28 described in conjunction with Figures 1 and 2. In this illustrative  
29 embodiment, a pair of piezo electric motion sensors 35 and 36 are  
30 employed in place of the single piezo electric relative motion sensor  
31 6 included in the embodiment shown in Figure 1. Each of the two piezo  
32 electric motion sensors 35 and 36 comprises the stacked or layered  
33 combination of the piezo electric disc element 37 sandwiched between  
34 the two sets of split electrodes 38 and 39, which combination is  
35 sandwiched between the two insulating discs or layers 40 and 41.  
36 This stacked or layered combination of the transducer disc elements  
37 are disposed in a closed cavity of the transducer container vessel 42  
38 in a compressed relationship against a thin end wall 43 of the closed

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1 cavity housing the transducer elements. An elongated vibration sensing  
2 members 44 with one extremity anchored to the reinforcing rib 45 that is  
3 disposed on a reference plane parallel to the plane of symmetry  
4 located intermediate the two thin planar members 46 and 47, extends  
5 from the thin end wall 43 of the closed cavity. The other extremity  
6 of the elongated vibration sensing members 44 of the each of the two  
7 piezo electric motion sensors 35 and 36 are under a pressurized contact  
8 with each of the two thin planar members 46 and 47 constituting the end  
9 walls of the two pressure compartments 48 and 49. It should be noticed  
10 that the piezo electric disc element 37 is disposed on a plane parallel  
11 to the thin end wall 43 of the closed cavity, which plane is perpen-  
12 dicular to the reference plane defined by the reinforcing rib 45.  
13 The stacked or layered combination of the transducer disc elements  
14 shown in Figure 2, or other modified versions thereof described in  
15 conjunction with Figure 2 can be employed in constructing the piezo  
16 electric motion sensors 35 and 36. It should be understood that the  
17 two electrical signals respectively generated by the two opposite  
18 halves of the piezo electric disc element respectively located on the  
19 two opposite sides of the reference plane are combined by means of a  
20 noise cancelling electrical circuit such as the one shown in Figure 2  
21 for each of the two piezo electric motion sensors 35 and 36, and then  
22 the two output electrical signals respectively supplied by the two  
23 piezo electric motion sensors 35 and 36 are combined again by using a  
24 second stage noise cancelling electrical circuit comprising the two  
25 amplifiers 50 and 51, and the signal level balancing means 52, which  
26 combination provides the alternating output electrical signal  
27 representing the vortex shedding from the bluff body. It can be readily  
28 realized that an economic version of the transducer providing the  
29 alternating output electrical signal representing the vortex shedding  
30 from the bluff body can be derived from the embodiment shown in Figure  
31 3 by eliminating one of the two piezo electric motion sensors 35 and  
32 36, one of the two thin planar members 46 and 47, and one of the two  
33 halves of the second pressure compartment 49 straddling the first  
34 pressure compartment 48. A vortex flowmeter with such an economized  
35 version of the transducer is claimed separately in the claims.  
36 In Figure 4, there is illustrated an embodiment of the capacitive  
37 transducer that can be employed in place of the piezo electric  
38 transducer 3 included in the embodiment shown in Figure 1. In this

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1 particular embodiment, the two thin planar members 53 and 54  
2 constituting the end walls of the two pressure compartments 55 and 56  
3 are disposed in a parallel relationship at a close proximity to one  
4 another in order to create a large electrical capacitance therebetween.  
5 A device 57 measuring the capacitance between the two thin planar  
6 members or other electrical variables related to the capacitance  
7 provides an alternating or fluctuating output electrical signal 58  
8 representing the vortex shedding from the bluff body. The device 57  
9 may be an instrument measuring the capacitance, or a detector or  
10 demodulator providing an electrical signal representing the envelope  
11 of a high frequency alternating electrical signal transmitted through  
12 an electrical circuit including a capacitor comprising the two thin  
13 planar members 53 and 54, wherein the high frequency alternating  
14 electrical signal oscillates at the resonance frequency of the  
15 electrical circuit with the two thin planar members under zero relative  
16 deflection therebetween. As the amplitude of the high frequency  
17 alternating electrical signal changes very sensitively as a function  
18 of the relative distance between the two thin planar members 53 and  
19 54, the envelope of the high frequency alternating electrical signal  
20 provides a fluctuating output electrical signal 58 representing the  
21 vortex shedding from the bluff body. Of course, the fluctuating output  
22 electrical signal 58 generated by the transducer shown in Figure 4  
23 can be readily converted to an alternating output electrical signal  
24 representing the vortex shedding from the bluff body by taking out  
25 the direct current component therefrom.

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1        The embodiments of the invention, in which an exclusive property  
2 or privilege is claimed, are defined as follows :

3        1. An apparatus for measuring flow rate of fluid comprising in  
4 combination :

5                a) a vortex generator of an elongated cylindrical shape  
6                disposed at least partially across a fluid stream,  
7                said vortex generator including a first hole with one  
8                extremity including at least one opening open to a first  
9                side surface of the vortex generator and a second hole  
10               with one extremity including at least one opening open to  
11               a second side surface of the vortex generator opposite to  
12               said first side surface;

13               b) a transducer body including a first pressure compartment  
14               with two opposite end walls provided by two thin planar  
15               members, and a second pressure compartment straddling the  
16               combination of the two thin planar members and the first  
17               pressure compartment, wherein the other extremity of the  
18               first hole included in the vortex generator is open to  
19               the first pressure compartment and the other extremity of  
20               the second hole included in the vortex generator is open  
21               to the second pressure compartment; and

22               c) a transducer means for converting a relative flexural  
23               vibration between the two thin planar members into a  
24               fluctuating electrical signal representing vortex shedding  
25               from the vortex generator.

26        2. An apparatus as defined in Claim 1 wherein said combination  
27        includes means for determining volume flow rate of fluid as a function  
28        of frequency of the fluctuating electrical signal.

29        3. An apparatus as defined in Claim 1 wherein said combination  
30        includes means for determining mass flow rate of fluid as a function  
31        of frequency and amplitude of fluctuation of the fluctuating electrical  
32        signal.

33        4. An apparatus as defined in Claim 1 wherein said transducer  
34        means comprises a piezo electric relative motion sensor including :

35                a) a transducer container vessel secured to the transducer  
36                body and having a closed cavity with two opposite thin  
37                walls disposed approximately parallel to a plane of  
38                symmetry located intermediate the two thin planar members

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1                   in a parallel relationship;

2                   b) a piezo electric disc element disposed within the closed

3                   cavity of the transducer container vessel on a plane

4                   approximately parallel to said plane of symmetry

5                   intermediate the two opposite thin walls of the closed

6                   cavity in a compressed relationship therebetween, said

7                   piezo electric disc element extending across a reference

8                   plane perpendicular to said plane of symmetry and

9                   intersecting with the two opposite thin walls of the

10                  closed cavity in a perpendicular relationship, and

11                  including at least two electrodes respectively located

12                  on two opposite sides of said reference plane;

13                  c) two elongated vibration sensing members respectively

14                  disposed next to the two opposite thin walls of the closed

15                  cavity, each of the two elongated vibration sensing

16                  members including an angled first extremity disposed on

17                  said reference plane and secured to each of the two opposite

18                  thin walls of the closed cavity, and an over-hanging

19                  second extremity under a pressurized contact with each of

20                  the two thin planar members; and

21                  d) means for combining two electrical signals respectively

22                  supplied by said at least two electrodes, wherein noise

23                  is cancelled out between the two electrical signals and

24                  a refined output electrical signal representing vortex

25                  shedding from the vortex generator is obtained.

26                  5. An apparatus as defined in Claim 1 wherein said transducer

27                  means comprises two piezo electric motion sensors, each of said two

28                  piezo electric motion sensors including :

29                  a) a transducer container vessel secured to the transducer

30                  body and having a closed cavity with a thin end wall

31                  disposed approximately perpendicular to a plane of

32                  symmetry located intermediate the two thin planar

33                  members in a parallel relationship;

34                  b) a piezo electric disc element disposed within the closed

35                  cavity of the transducer container vessel on a plane

36                  approximately perpendicular to said plane of symmetry

37                  in a compressed relationship against the thin end wall

38                  of the closed cavity, said piezo electric disc element

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1 extending across a reference plane parallel to said  
2 plane of symmetry and intersecting with the thin end wall  
3 of the closed cavity in a perpendicular relationship,  
4 and including at least two electrodes respectively located  
5 on two opposite sides of said reference plane;

6 c) an elongated vibration sensing member extending from the  
7 thin wall of the closed cavity, said elongated vibration  
8 sensing member including a first extremity disposed on  
9 said reference plane and secured to the thin wall of the  
10 closed cavity, and an over-hanging second extremity  
11 under a pressurized contact with each of the two thin  
12 planar members; and

13 d) means for combining two electrical signals respectively  
14 supplied by said at least two electrodes, wherein noise  
15 is cancelled out between the two electrical signals and  
16 a single electrical signal representing flexural  
17 vibration of each of the two thin planar members is  
18 obtained;

19 wherein said combination further includes means for combining the  
20 single electrical signal provided by one of the two piezo electric  
21 motion sensor and the single electrical signal provided by the other  
22 of the two piezo electric motion sensor, wherein noise is cancelled  
23 between said two single electrical signals and a refined output  
24 electrical signal representing vortex shedding from the vortex  
25 generator is obtained.

26 6. An apparatus as defined in Claim 1 wherein said transducer  
27 means comprises means for producing an output electrical signal  
28 representing value of electrical capacitance between the two thin  
29 planar members as a measure of vortex shedding from the vortex  
30 generator.

31 7. An apparatus for measuring flow rate of fluid comprising in  
32 combination :

33 a) a vortex generator of an elongated cylindrical shape  
34 disposed at least partially across a fluid stream,  
35 said vortex generator including a first hole with one  
36 extremity including at least one opening open to a first  
37 side surface of the vortex generator and a second hole  
38 with one extremity including at least one opening open to

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- 1        a second side surface of the vortex generator opposite to  
2        said first side surface;
- 3        b) a transducer body including a first and second pressure  
4        compartment separated by a thin planar member constituting  
5        a common end wall of the first and second pressure  
6        compartment, wherein the other extremity of the first hole  
7        included in the vortex generator is open to the first  
8        pressure compartment, and the other extremity of the second  
9        hole included in the vortex generator is open to the second  
10       pressure compartment; and
- 11        c) a piezo electric motion sensor including :
  - 12        1) a transducer container vessel secured to the transducer  
13        body and having a closed cavity with a thin end wall  
14        disposed approximately perpendicular to the thin planar  
15        member;
  - 16        2) a piezo electric disc element disposed within the closed  
17        cavity of the transducer container vessel on a plane  
18        parallel to the thin end wall of the closed cavity,  
19        said piezo electric disc element extending across a  
20        reference plane approximately parallel to the thin planar  
21        member and intersecting with the thin end wall of the  
22        closed cavity in a perpendicular relationship, and  
23        including at least two electrodes respectively located  
24        on two opposite sides of said reference plane;
  - 25        3) an elongated vibration sensing member extending from  
26        the thin end wall of the closed cavity, said elongated  
27        vibration sensing member including a first extremity  
28        disposed on said reference plane and secured to the  
29        thin end wall of the closed cavity, and an over-hanging  
30        second extremity under a pressurized contact with the  
31        thin planar member; and
  - 32        4) means for combining two electrical signals respectively  
33        supplied by said at least two electrodes, wherein noise  
34        is cancelled between the two electrical signals and  
35        a fluctuating output electrical signal representing  
36        vortex shedding from the vortex generator is obtained.
- 37        8. An apparatus as defined in Claim 7 wherein said combination  
38        includes means for determining volume flow rate of fluid as a function

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1 of frequency of the fluctuating output electrical signal.  
2 9. An apparatus as defined in Claim 7 wherein said combination  
3 includes means for determining mass flow rate of fluid as a function  
4 of frequency and amplitude of fluctuation of the fluctuating output  
5 electrical signal.

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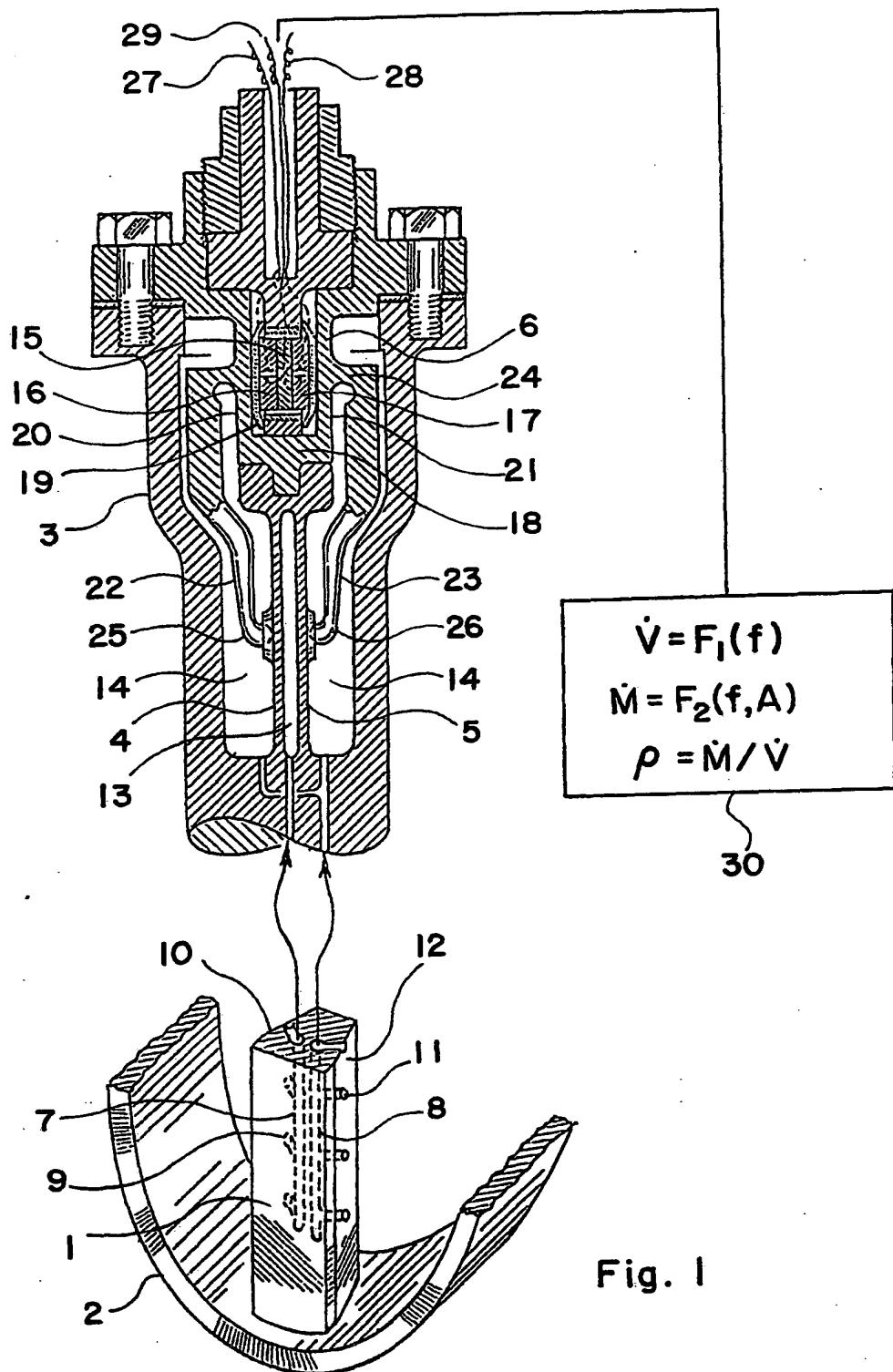
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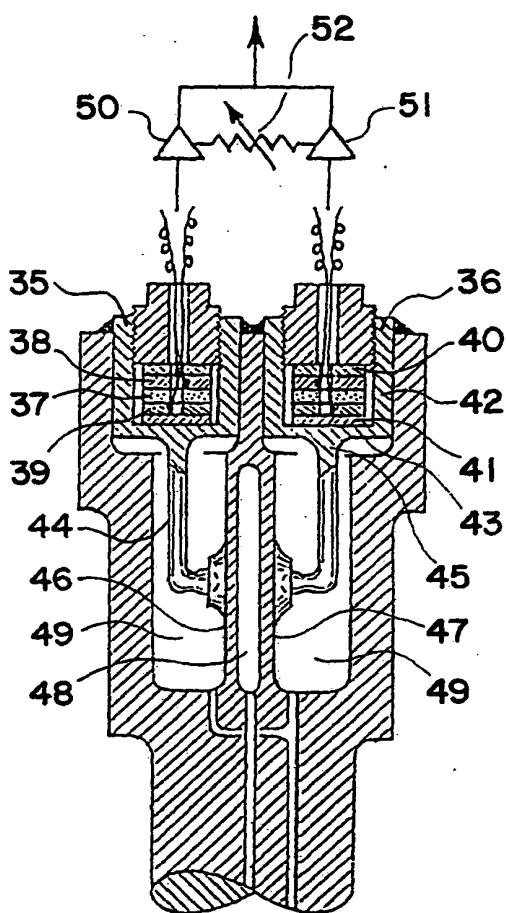
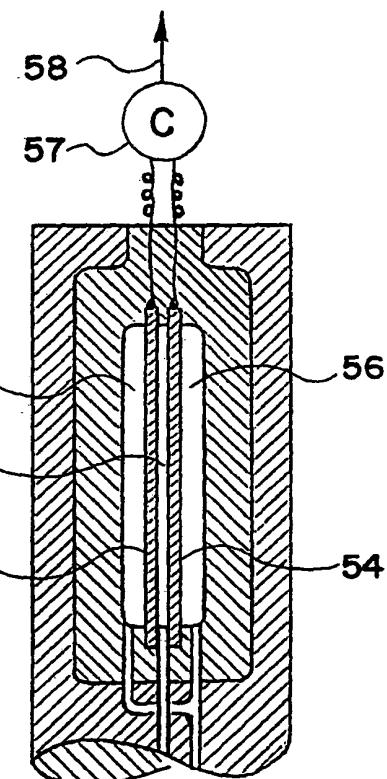
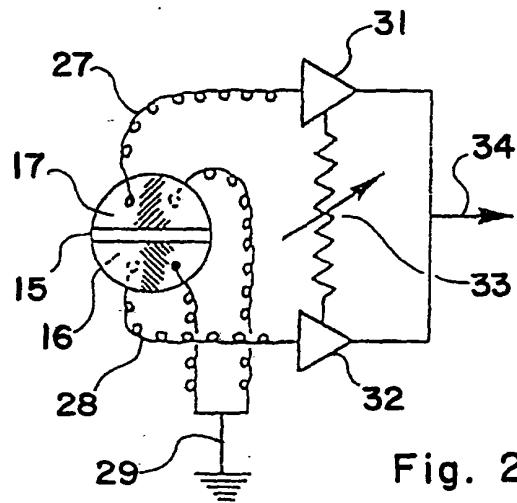
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## INTERNATIONAL SEARCH REPORT

PCT/US92/08504

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G01F 1/32

US CL :73/861.24

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 73/861.22; 73/861.24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,803,870 (Lew) 14 February 1989	1-9
A	US, A, 4,161,878 (Fussel Jr.) 24 July 1979	1-9
A	US, A, 4,440,027 (Focht) 03 April 1984	1-9
A	US, A, 4,879,909 (Lew) 14 November 1989	1-9

Further documents are listed in the continuation of Box C.

See patent family annex.

Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

07 DECEMBER 1992

Date of mailing of the international search report

05 JAN 1993

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